EEE 313 - Electronic Circuit Design - Term Project
Design Phase Report

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"I affirm that I have not given or received any unauthorised help on this report and that this work is my own."

My Signature : 

1. Offset Voltage Measurements:

The IC LM324 is a Quad-Opamp that features 4 Opamps. The Opamps are numbered as shown in Figure 1.1.

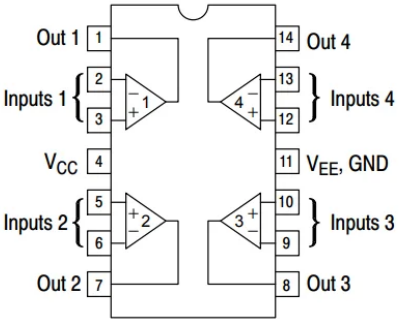

Figure 1.1: LM324 Pinout

The measurements of the OPAMPs of a Quad-Opamp LM324 are given in table 1. These voltages were measured according to the theory provided in [1].

Voltages	Opamp 1	Opamp 2	Opamp 3	Opamp 4
Vo1 (On,On)	-0,324	-1,869	-0,558	-0,956
Vo2 (On,Off)	-3,037	-4,69	-3,204	-3,617
Vo4 (Off,On)	2,497	0,74	2,021	1,7
Vo4 (Off,Off)	-0,234	-2,042	-0,643	-0,921

Table 1: Opamp Voltage Measurements

Then, these values were inserted into the given spreadsheet[2] to calculate their respective voltage and current offset values. These values are available in Table 2.

	Opamp 1	Opamp 2	Opamp 3	Opamp 4
VIO	0,32	1,87	0,56	0,96
IB2	-27,13	-28,21	-26,46	-26,61
IB1	-28,21	-26,09	-25,79	-26,56
IIO	-0,90	1,73	0,85	-0,35
IB1-IB2	-1,08	2,12	0,67	0,05

Table 2: Offset Values

I also took some pictures while measuring the voltages in Table 1. Those pictures are located in the appendix.

The offset voltage difference needs to be minimal between the input OPAMPs of the instrumentation amplifier. That is why Opamp 1 and Opamp 4 have been chosen. They are geometrically close on the IC and have similar values.

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2. LTSpice “opamp2offset” Models:

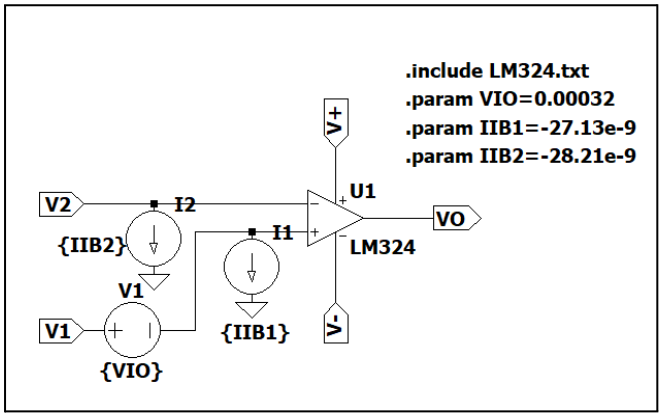

Figure 2.1: “opamp2offset.asc” for Opamp1

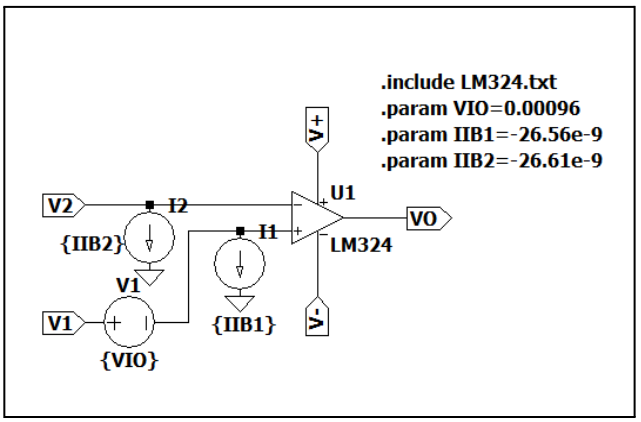

Figure 2.2: “opamp2offset4.asc” for Opamp4

The offset parameters that we calculated are then entered into LTSpice to simulate the non-ideal Opamps. These Opamps are then used to design the main project schematic that includes the instrumentation amplifiers.

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3. LTSpice Simulations:

While implementing the circuit in LTSpice, there were three main criteria that the design must satisfy. The LTSpice schematic of the circuit was provided in the appendix.

- The output voltage at 2V±0.5V when the thermocouple is at room temperature (thermocouple output voltage is zero).

- The output voltage is 9V±1V when the temperature is at the required temperature (thermocouple voltage is $39.2 \times T_S\ \mu V$)

- LED turns ON when the heater resistance is being heated. It should turn OFF when the heater is OFF.

  My Bilkent ID is 22201730, consequently, $mod(22201730, 40) = 10$. Therefore, I had to keep the resistance 40K above room temperature. A 40K difference results in a 15.68mV voltage difference across the thermocouple.

The thermocouple was simulated with a voltage source set to DC Sweep from 0V to 2mV. The results are as shown in Figure 3.1, 3.2.

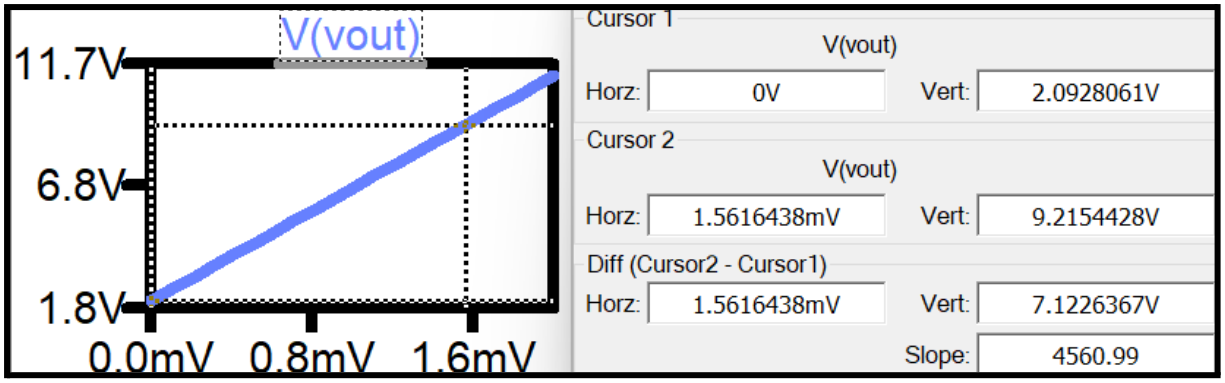


Figure 3.1: Vout as a Function of Thermocouple Voltage

Figure 3.1 shows that $V_{out} = 2V$ when $V_{TC} = 0$. Where, V_{TC} is the thermocouple voltage. It also shows that $V_{out} \simeq 8.7V$ when $V_{TC} = 1.56mV$ ($V_{TC} = 1.56mV$ when $T_S = 40K$) Also, 8.7V is in the acceptable range of $9V \pm 1V$. Therefore, the design satisfies the first and second criteria.

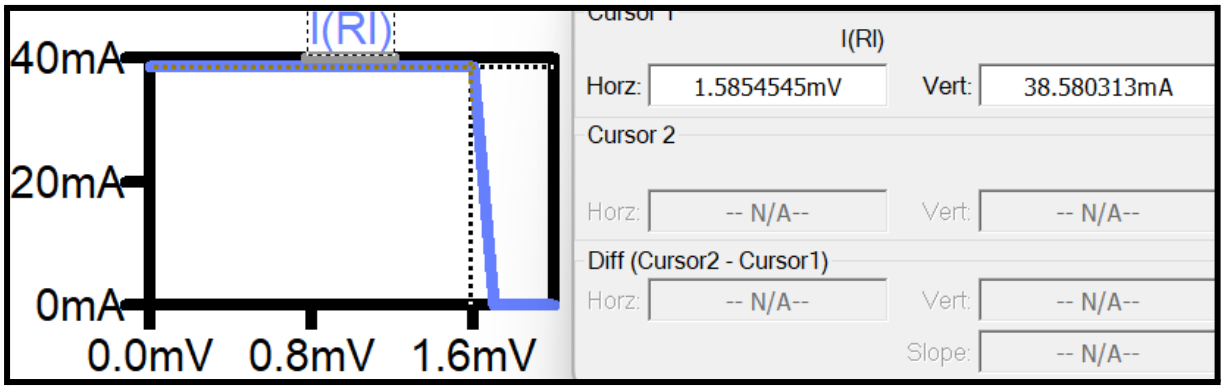


Figure 3.2: Diode current as a Function of Thermocouple Voltage

Figure 3.2 shows the LED turning off after $V_{TC} > 1.58mV$. This is because $V_{TC} = 1.58mV$ is the instance that our resistor has reached the desired temperature which is the threshold for heating. When V_{TC} goes above this value, there should no longer be any current flow through the load. Hence, the LED is also off. So the design satisfies the third criterion. We can also see that LED current is correlated with the load current.

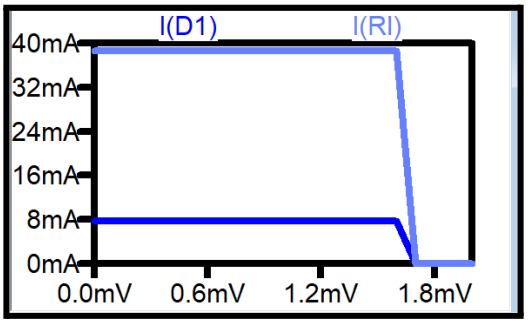
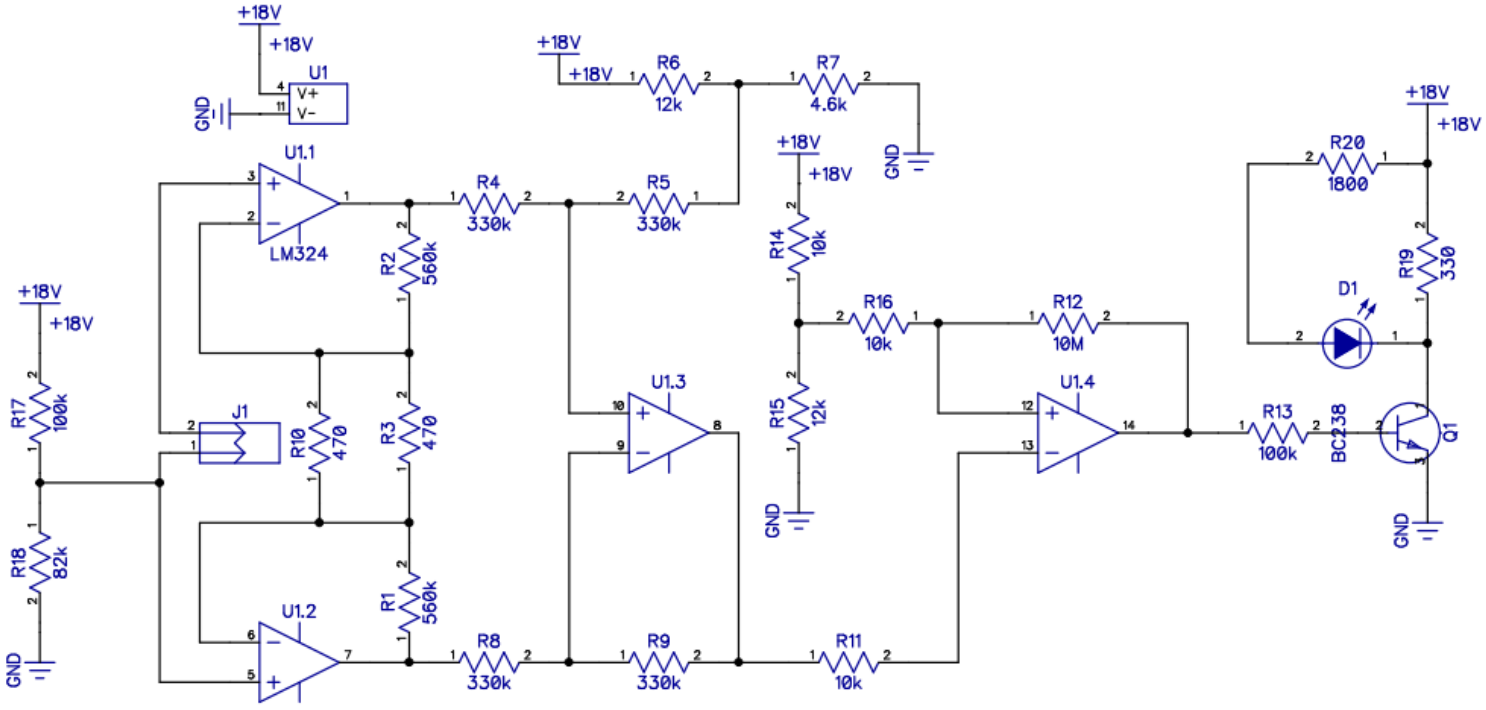


Figure 3.3: LED and Load Currents

4. Diptrace Schematic:



#	Name	Manufacturer	Quantity	Value	RefDes
1	LED-3mm Round Red	Kingbright	1		D1
2	Terminal (Screw)	Molex	1		J1
3	BC238		1	BC238	Q1
4	Resistor420		2	560k	R1, R2
5	Resistor420		2	470	R3, R10
6	Resistor420		4	330k	R4, R5, R8, R9
7	Resistor420		2	12k	R6, R15
8	Resistor420		1	4.6k	R7
9	Resistor420		3	10k	R11, R14, R16
10	Resistor420		1	10M	R12
11	Resistor420		2	100k	R13, R17
12	Resistor420		1	82k	R18
13	Resistor420		1	330	R19
14	Resistor420		1	1800	R20
15	LM324	Texas Instruments	1	LM324	U1

Figure 4.1: Diptrace Schematic and Component List

5. Conclusion

To summarise, we used a thermocouple to control the temperature of a resistor. We achieved this through an instrumentation amplifier that mitigated the offset voltages of the opamps.

6. References

[1]*Instrumentation Amplifier*, Moodle files, Electrical Engineering, Bilkent University, Oct. 20, 2024.

[2]*Input Offset Calculator*, Spreadsheet, Electrical Engineering, Bilkent University, Oct. 20, 2024 (unpublished).

Appendix

a) LTSpice Schematic

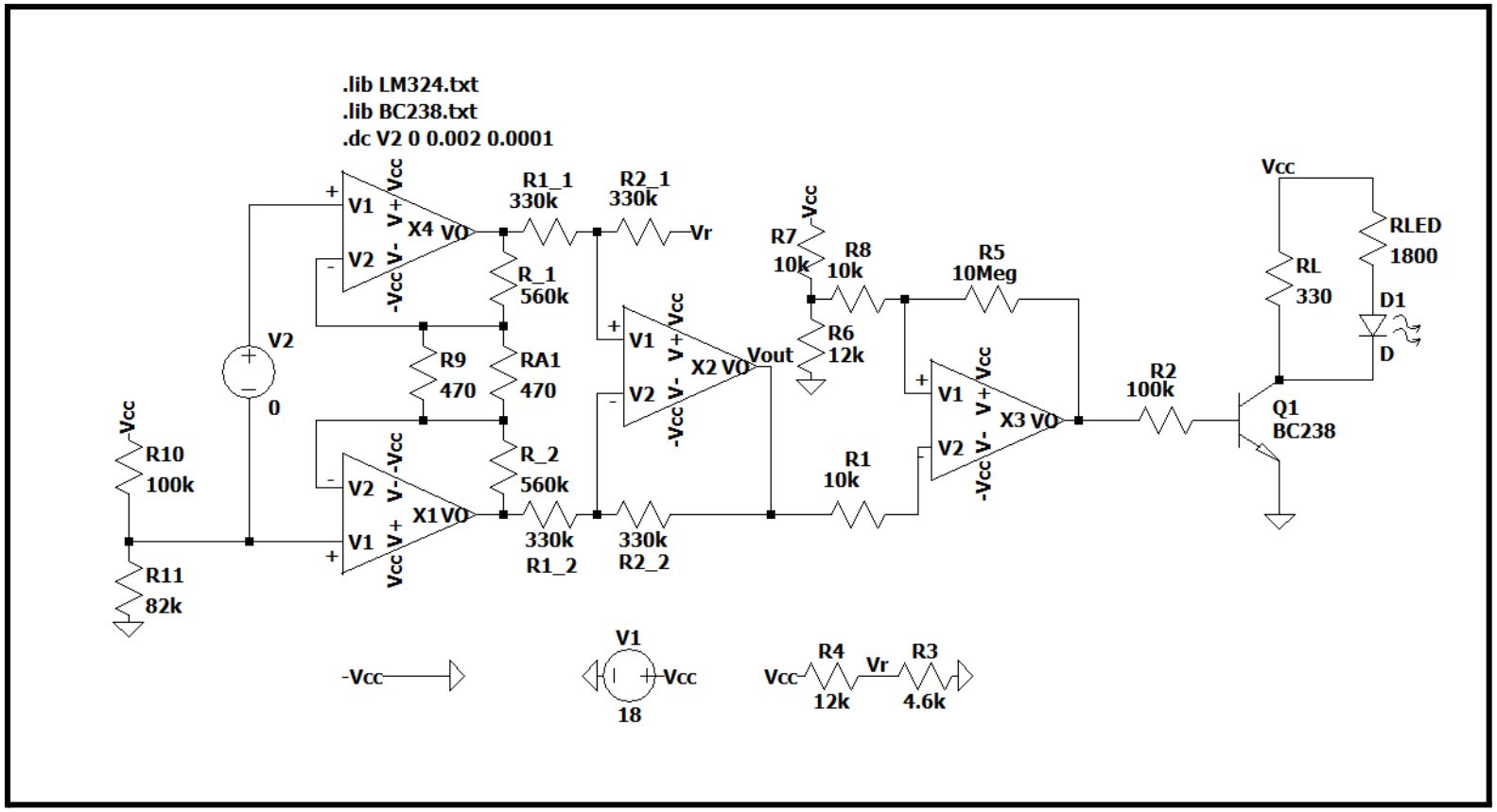
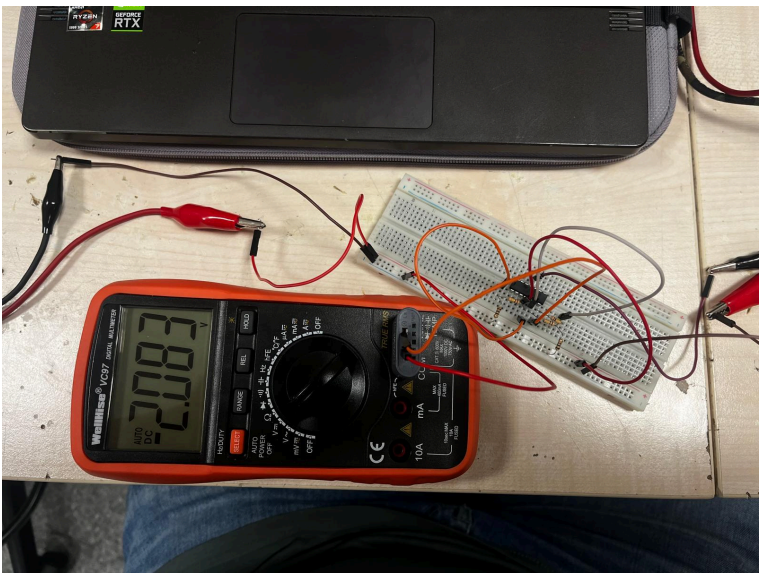


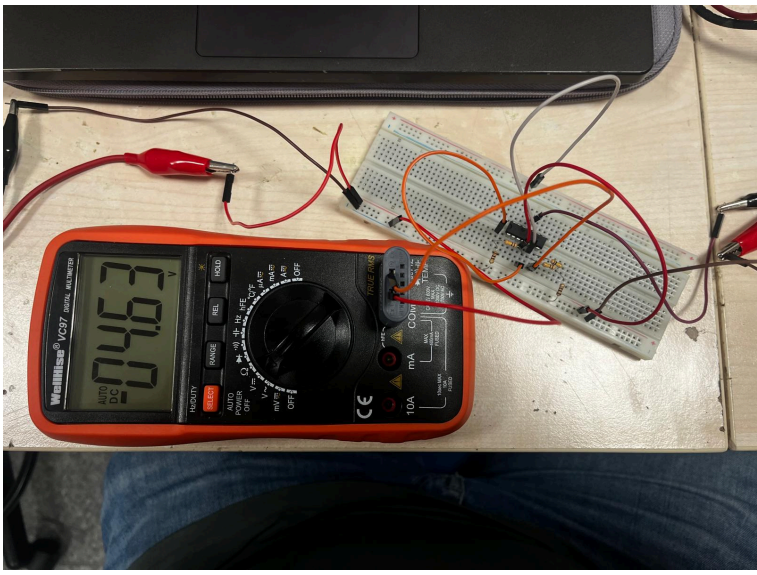
Figure A1: LTSpice Schematic

X4 in the given schematic utilises the opamp2offset4 symbol and X1 utilises the opamp2offset symbol. X2 and X3 Opamps' offsets are negligible and opamp2offset was used.

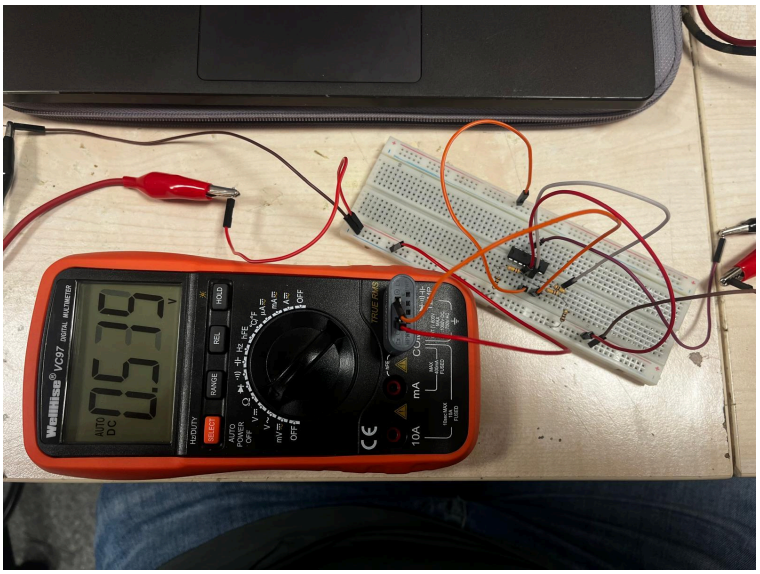
b)Opamp Measurements



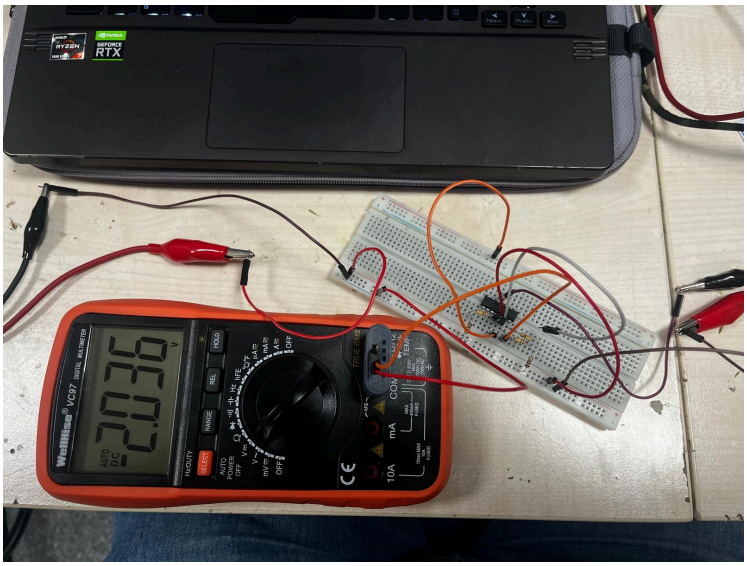
Figıre B1: V_{01} Measurement



Figıre B2: V_{02} Measurement



Figıre B3: V_{03} Measurement



Figıre B4: V_{04} Measurement